International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 5, Issue 2, Apr 2015, 51-64

FUZZY BASED OPTIMIZATION OF CUTTING PARAMETERS FOR TURNING OPERATION

G. VELAYUDHAM

Assistant Professor, College of Food and Dairy Technology, Chennai, Tamil Nadu, India

ABSTRACT

Tool wear is an important phenomenon which directly affects the work piece dimensions and surface quality. A reliable and sensitive technique for monitoring the tool wear without interrupting the process and it is crucible in realization of modern manufacturing systems like unmanned machining centers, adaptive control optimization etc, and the project contributes to suggest the fuzzy based optimization of cutting parameters such a depth of cut, feed rate and tangential force. Cutting force is the major criteria that plays vital role in tool wear, when more force is induced in tools and it wear out rapidly. Optimum cutting force is essential to effectively utilize the tool and minimize the cost in various aspects. In this experiment the lathe tool dynamometer is used to monitor the cutting force of mild steel work by tungsten carbide tool, by varying the feed rate and depth of cut. Designing of fuzzy model for optimizing the strategic decision can be very helpful to protect the failures in the system. The above problem can be easily countered by the fuzzy logic, because fuzzy logic has ability to deal with uncertainty and multi-valued logic and result is complied by MAT-Lab.

KEYWORDS: Fuzzy Logic, Feed, Depth of Cut, Tangential Force, Lathe Tool Dynamometer, Turning Operation

INTRODUCTION

The types of tool material are plain carbon steel, medium alloy steel, high speed steel, satellites, cemented carbides, ceramics, diamonds and abrasives etc. in the process of cutting metals and the tool is worn as a result of friction of chip on the tool face and of the tool flanks on the work. Tool wear involves abrasion and the removal of micro particle of the surfaces as well as microscopic shaping of the cutting edge. The physics of tool wear in metal cutting is very complicated. It involves abrasive, adhesive and diffusive wear. The abrasive wear resulting from scouring the cutting away of microscopic volumes of tool materials by the inherently hard structural constituents of the metal being machined. A skin on casting or scale on forging also produces a serve abrasive effect. Adhesive wear results from the action of the considerable forces of molecular adhesion between the work material and the tool. As the chip slides it tears away minute particles of the tool material. The diffusive wear occurs as the result of the material dissolution of the reacting materials of the work-tool pair. To detect the tool wear during the machining operation, we use the instrument called lathe tool dynamometer.

The advents of electronics innovative idea and improved material technology have made measurements of the above mentioned parameters simply, accurate reliable and consistent. A whole new range of transducer for measurements of various parameters and for a variety of application is available in the market today.

DESCRIPTION

Lathe tool dynamometer is a recent development in electronic field of measurements. It is very useful device in

machine tool design. It helps the tool designer to have ands accelerate knowledge of the different forces involved in turning operation and to design the tool for maximum efficiency. This knowledge is necessary in the tool design to decide the strength and rigidity of the structures and components and the required power of the motor. In the turning operation the major forces involved are tangential, feed and radial. The lathe tool dynamometer employs strain gauges to sense the forces. These signal form strain gauges, when processed in suitable for instrumentations and amplifiers for represents the forces developed during turning operation. These three forces are displayed on three separate 3 ½ digit LED displays. The dynamometer comprises of the sensing elements bonded with strain gauges with provisions to fix the turning tool and clamp rigidity. Then the dynamometer fitted on the tool post of the lathe. When the work piece is being machined the tangential, feed and radial forces associated are displayed on the indicators.

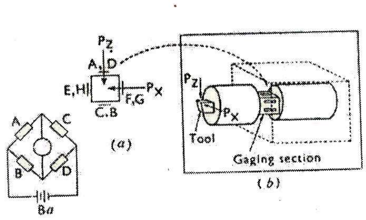


Figure 1: Lathe Tool Dynamometer

PROBLEM IDENTIFICATION

Forces in Metal Cutting

It is very difficult to accurately predict the cutting forces encountered in the metal cutting operations due to high cutting speeds. We will study how the cutting forces are influenced by the following most important variables like cutting speed and cutting fluid and effective rake. At high speeds the forces can be predicted quite accurately due to absence of built- up-edge. It can be found that cutting fluids do not influences cutting forces appreciably at high speeds. However at lower speeds the cutting forces can be varying in an unpredictable manner. The cutting force reduces considerably with increase in the effective rake in the positive direction and in oblique cutting at different angles. This is due to shear plane area as the rake increases (which increases shear angle). Thus to reduce the hardness +ve rake angle is provided on the HSS tool depending on the cutting force and material being cut. For these -V_e rake is provided but high speeds can be adopted due to high resistances to thermal softening of the materials. As the cutting speed is increased with the ceramic tools having –V_e rake angle the area of the shear plane also decreases. The cutting forces are not much affected by increase in rake angle due to closer approach to adiabatic condition which results in higher strain rates and higher thermal softening effect of the work material. The magnitude and direction of cutting forces involved in machining processes help in the design and selection of machine tools, cutting tools and accessories. The resultant cutting force P acting in the oblique direction can be resolved along the three perpendicular axes x, y, and z. P_Z the main or tangential components (shown vertically) determine the torque on the main drive mechanism the deflection of the tool and required power. This component acts in the direction of the cutting speed. P_X, the axial component, acts in the direction of the tool traverse and it is at right angles to Pz and contribute a very little to the power consumption. P_Y, the radial components act along the tool shank and perpendicular to the other two components it has no share in the power consumption. The ratio of P_X, P_Y, and P_Z varies with geometry of the tool and to some extent the feed rate. For a 60-approach angle turning tool, they are approximately in the ratio of 3:1:1:2. These three components of force can be measured with a three components dynamometer. The factors affects the cutting forces are

- Work material
- Cutting speed
- Feed rate
- Depth of cut
- Approach angle

We are considering the following factors

- Depth of cut
- Feed rate
- Force

NEED OF FUZZY

Cutting forces is major criteria that plays vital role in tool wear, when cutting forces is more in tools, it wear out rapidly. Optimum cutting forces is essential to effectively utilize the tools and minimize the costs in various aspects. Nowadays, there are many optimizing techniques, but they have lot of calculations and mathematical derivation and complex also. By choosing fuzzy logic the complexity of calculation and mathematical derivation can be avoided using fuzzy rules and evaluation process

FUZZY CONTROLLER

In general fuzzy controllers are special expert systems. It employs a knowledge base technique and expressed in term of relevant fuzzy inferences rules and an appropriate inference engine to solve a given control problems. Fuzzy controller varies substantially according to the nature of problems they are supposed to solve. Control problem range is very complex tasks and typical in robotics which required a multitude of coordinated actions to simple goals,

Fuzzy controllers contrary to classical controllers are capable of utilizing knowledge elicited from human operators. This is crucial in control problems for which it is difficult or even impossible to construct precise mathematical or for which the acquired models are difficult or expensive to use. These difficulties may result from inherent non linearity, the time varying nature of the process to be controlled at unpredictable environment disturbances degrading sensors or other difficulties in obtaining precise and reliable measurements and host of other factors. It has been observed that experienced human operator is generally able to perform well under these circumstances

The knowledge of an experienced human operator may be used as an alternative to a precise model of the controlled process. While this knowledge is also difficult to express in precise terms, an imprecise linguistic description of the manner of control can utilize be articulated by the operator with relative ease.

A general fuzzy controller consists of four modules

- A fuzzy rule base
- A fuzzy inference engine

- Fuzzification module
- Defuzzification module

These are shown in figure

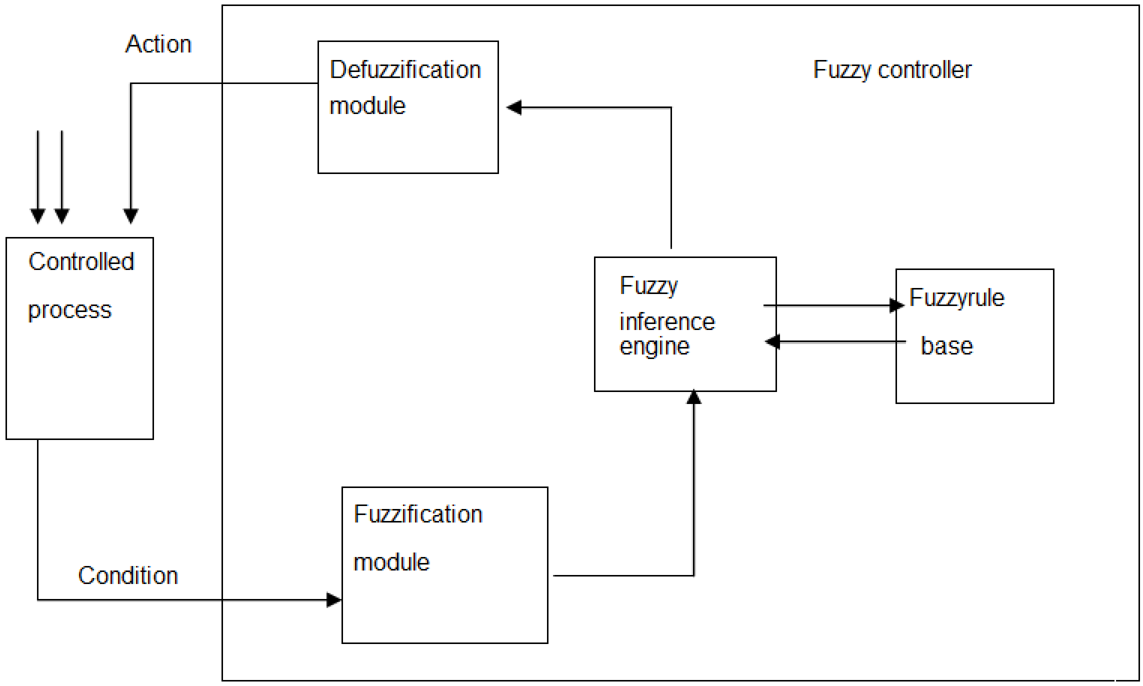


Figure 2: A General Fuzzy Controller

A fuzzy controller operates by repeating a cycle of the following four steps, First measurements are taken of all variable that represents relevant conditions of the controlled process. Next these measurements are converted in to appropriate fuzzy sets to express measurements un-certainties. This step is a called a fuzzification. The inference engine to evaluate the control rules stored in the fuzzy rule base then uses the fuzzified measurements. The result of this evaluation is a fuzzy set defined on the universe of possible actions. This fuzzy is then converted, in the final step of the cycle in to a single (crisp) value that is some sense is the best representation of the fuzzy set. This conversion is called a defuzzifaction. The defuzzified value represents actions taken by the fuzzy control cycles. To characterize the steps involved in designing fuzzy controller, let us consider a very simple control problem, and the problem of keeping desired value of a single variable in spite of environment disturbances. Let us now discuss the basic steps involved in the design of fuzzy controllers and illustrated.

The design involves the following five steps

Step 1

After identifying relevant input and output variable of the controller with the ranges of their values, we have to select meaningful linguistic states for each variable and express them by appropriate fuzzy sets.

Step 2

In this step a fuzzification function is introduced for each input variable to express the associated measurements uncertainty. The purpose of the fuzzification function is to interpret measurements of input variable each expressed by a

real number as more realistic fuzzy approximation of the respective real numbers.

Step 3

In this step knowledge pertaining to the given control problem is formulated in terms of a set of fuzzy inferences rules. There are two principal ways in which relevant inference rules can be determined. One way is to elicit them from experienced human operators. The other way is to obtain them from empirical data by suitable methods usually with the help of neural network.

Step 4

Measurements of input variable of a fuzzy controller must be properly combined with relevant fuzzy information rules to make inference regarding the output variable. This is the purpose of the inference engine.

Step 5

In this step of the design process, designer of a fuzzy controller must select suitable defuzzification methods. The purpose of defuzzification is to convert each conclusion obtained by the inference engine, which is expressed in term of a fuzzy set to controller and is not arbitrary. It must sense and summarize the elastic constraint imposed on possible values of the output variable by the fuzzy set. The number of defuzzification methods leading to distinct results was proposed in the literature. Each method is based on some rationale.

EXPERIMENTAL SET UP

In this section a complete set of experimental data used to predict the cutting force "F" based on a measure of the feed rate "f" and the depth of cut "d" during turning operations. The measurements were taken on a conventional lathe equipped with Lathe tool dynamometer with carbide tipped tool. The job or work was mild steel material of diameter 25 mm. The cutting forces were measured under two experimental conditions by keeping the constant feed rate with varying depth of cut and constant cutting depth of cut with variable feed rate. The readings are tabulated in a tabular column.

EXPERIMENTAL PROCEDURE

- The dynamometer calibrated for checking the performance in the lathe.
- Then the dynamometer is rigidly fitted on the tool post of lathe machine. It should be carefully noted that the screw should not damage the sensor wire.
- Tool is inserted in the tool holder and tightened properly.
- The cable of the lathe tool dynamometer is connected to rear panel which indicates the force in digital output.
- The panel wire is connected to the power supply.
- Switch ON the power to the indicator.
- Initially make all the three displays to zero by adjusting the adjustment to zero control.
- Now the setup is ready to make measurements.
- Set the job in the chuck, using a key.

- Start the machine, by varying the feed rate and depth of cut in the given job.
- Notes the feed and depth of cut values.
- The corresponding three forces (i.e. tangential, feed, and radial) were shown in the indicator in Newton (N).
- Then by keeping the feed rate constant varying the depth of cut, the corresponding forces are noted on the tabular column.
- After that, keep the depth of cut may be constant by varying the feed rate and noted in the tabular column.
- The above procedure is repeated of different number of feeds and the corresponding readings are tabulated.

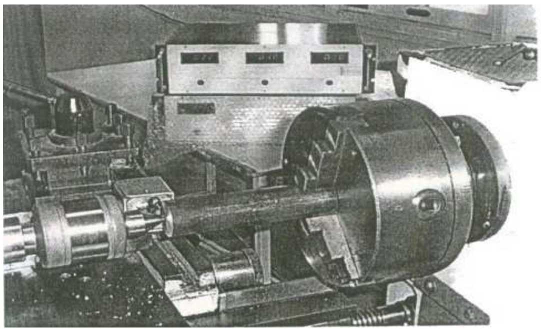


Figure 3: Turning Operation in Lathe

TABULATION FOR EXPERIMENTAL READINGS

Table 1: Experimental Reading

S. No	Feed mm/rev	Depth of Cut mm	Tangential Force N
1.	0.078	0.2	4
2.	0.078	0.4	5
3.	0.078	0.6	8
4.	0.078	0.8	13
5.	0.078	1.0	14
6.	0.101	0.2	1
7.	0.101	0.4	5
8.	0.101	0.6	7
9.	0.101	0.8	13
10.	0.101	1.0	16
11.	0.1562	0.2	5
12.	0.1562	0.4	7
13.	0.1562	0.6	11
14.	0.1562	0.8	20
15.	0.1562	1.0	22

RESULTS AND DISCUSSIONS

From the experiment, the mild steel was used as the work piece material and tungsten carbide tool as the cutting tool. The tool geometry, tool height, and tool overhang are maintained uniformly for all the set of readings. The work piece was held in three jaws chuck and other parameters were set required for the particular experiments. A total number of 15 set of readings were taken. The cutting condition used and the output parameter of the work piece produced change in voltage signal from the sensing unit, from that we will get force as digital output.

INPUT ACQUISTION

After identifying the relevant input and output variables such as feed, depth of cut and force of the controller the ranges of their values have selected with meaningful linguistic states for each variable and expressed them by appropriate fuzzy sets.

The linguistic variables are

- VL - very Low
- L -Low
- M -Medium
- H - High
- VH - Very High

Representing these linguistic states by triangular shape fuzzy number that are equally spread over each range, we obtained the fuzzy quantization for linguistic variables. The ranges are grouped based on the experimental work and literature survey. The range tables are given below.

Feed Rate

Table 2: Ranges of Feed Rate in mm/rev

S. No	Minimum	Maximum	Category
1.	0.05	0.2	Very low
2.	0.1	0.4	Low
3.	0.3	0.6	Medium
4.	0.5	0.8	High
5.	0.7	1.0	Very low

Depth of Cut

Table 3: Range of Depth of Cut in Mm

S. No	Minimum	Maximum	Category
1.	0.05	0.3	Very low
2.	0.15	0.5	Low
3.	0.35	0.7	Medium
4.	0.55	0.9	High
5.	0.75	1.1	Very high

Force

Table 4: Forces in N

S. No	Minimum	Maximum	Category
1.	0	20	Very low
2.	10	40	Low
3.	30	60	Medium
4.	50	80	High
5.	70	100	Very high

FUZZIFICATION

A fuzzification is a function is introduced for each input variable to express the associated measurements uncertainty. The purpose of fuzzification function is to interrupt measurements of inputs variables, each expressed by a real number as more realistic fuzzy approximation of the respective real number. The fuzzy membership grades for the readings were given below. Calculation of membership grades are done by mathematical method.

Depth of Cut

Table 5: Membership Grade for Depth of Cut

S. No	Minimum	Maximum	Parameter	Membership Grade	Category
1.	0.05	0.3	0.2	0.8	Very low
2.	0.15	0.5	0.2	0.285	Low
3.	0.15	0.5	0.4	0.571	Low
4.	0.35	0.7	0.4	0.285	Medium
5.	0.35	0.7	0.6	0.571	Medium
6.	0.55	0.9	0.6	0.285	High
7.	0.55	0.9	0.8	0.571	High
8.	0.75	1.1	0.8	0.285	Very high
9.	0.75	1.1	1.0	0.571	Very high

Feed

Table 6: Membership Grade for Feed Rate

S. No	Minimum	Maximum	Parameter	Membership Grade	Category
1.	0.05	0.2	0.078	0.3733	Very low
2.	0.05	0.2	0.101	0.68	Very low
3.	0.1	0.4	0.101	0.0667	Low
4.	0.05	0.2	0.156	0.584	Very low
5.	0.1	0.4	0.156	0.3746	Low
6.	0.1	0.4	0.202	0.6833	Low
7.	0.1	0.4	0.312	0.5833	Low

MODEL CALCULATION FOR MEMBERSHIP GRADE

RANGE: 0.5-0.8

FEED: 0.625

0.5+0.8/2=0.65

(0.5,0) (0.65,1)

X1, Y1 X2, Y2

(Y-Y1)=M(X-X1)

M=Y2-Y1/X2-X1

(Y-0)=(Y2-Y1)(X-0.5)/(X2-X1)

Y= (1-0)/(0.65-0.5)

=1/0.15(0.625-0.5)

Y=0.125/0.15

Y=0.833

INFERENCE

The knowledge pertaining to give control program is formulated in terms of a set of fuzzy inference rules. There are two principle ways in which relevant inference rules can be determined. One way is to elicit them from experienced human operators. The other way is to obtain them from empirical data by suitable learning methods. Here we have framed the rules from the experimental data. The inference rules are shown below.

Table 7: Rule for Feed Rate, Depth of Cut and Force

S.No	Feed Mm/Rev	Depth of Cut Mm	Tangential Force N
1.	Very low	Very low	Very low
2.	Very low	Medium	Very low
3.	Very low	Medium	Very low
4.	Low	Very low	Very low
5.	Low	High	Low
6.	Low	Medium	Medium
7.	Low	High	Low
8.	Medium	Very low	Medium
9.	Medium	Medium	Medium
10.	Medium	High	Medium
11.	Medium	Very low	Very low
12.	High	Very high	High (very high)
13.	High	High	High
14.	Very high	High	High
15.	Very high	Very high	Very high

Fuzzy Rules

- If FEED is VERY LOW and DEPTH OF CUT IS MEDIUM

  Then force of VERY LOW

- If FEED is MEDIUM and DEPTH OF CUT is MEDIUM

  Then force is LOW.

- If FEED is MEDIUM and DEPTH OF CUT is VERY HIGH

  Then force is MEDIUM

- If FEED is HIGH and DEPTH OF CUT is HIGH

  Then force is HIGH.

- If FEED is VERY HIGH and DEPTH OF CUT is VERY HIGH

  Then force is VERY HIGH.

DEFUZZIFICATION

Step 1

Getting input value

Feed rare =0.078 (mm/rev)

Depth of cut =0.6 (mm)

Membership grades for feed rate

Y1 = 0.03733 (VL)

Membership grades for depth of cut

Y1 = 0.5714(M)

Y1 =0.2857(H)

Step 2

Applying fuzzy rule base

We get the combination of feed rate and depth of cut

0.3733.1 (AND) 0.5714 = 0.3733

(VL) (M) = (VL)

O.3733 (AND) 0.2857 = 0.2857

(VL) (H) = (L)

Step 3

0.3733(OR) 0.2857 = 0.3733(VL)

Step 4

The force is at very low range 0-20

Therefore the fuzzy value of force is

=0.3733*10 (avg force value in the very low range)

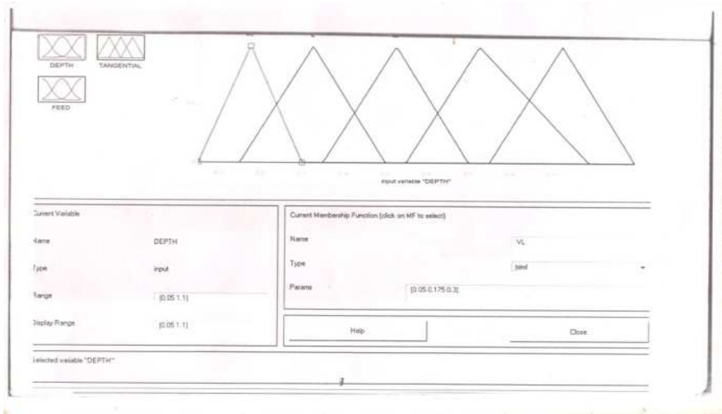
=0.3733

=4N

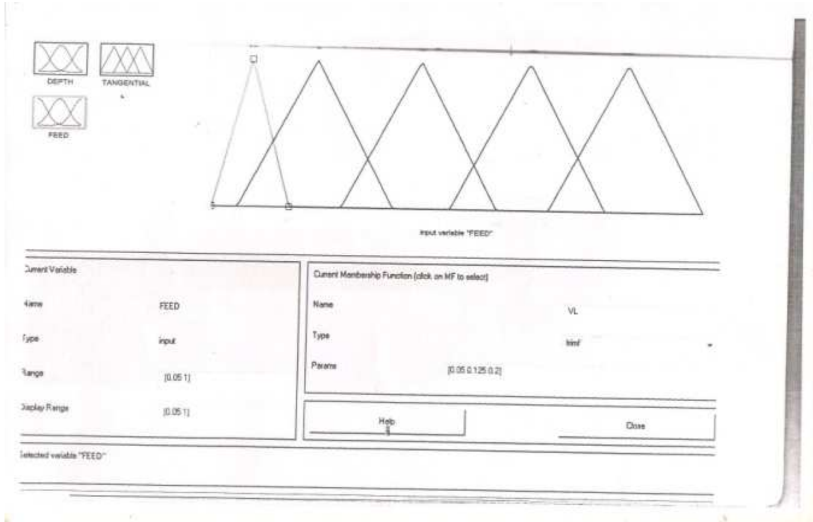
CONCLUSIONS

Optimization is famous techniques which are used to prevent to the machine tool failure. In this project work, a unique solution for optimize the cutting parameters such as feed rate and depth of cut. From the machining process, these two parameters are evolving the cutting force. If Very high cutting force may lead to cutting tool failure and poor leads to affect the production rate. Optimization of cutting force can optimizing the inherent input parameters of depth of cut and feed rate. The fuzzy based approach gives the better optimized force that can be automatically feed for the machine by

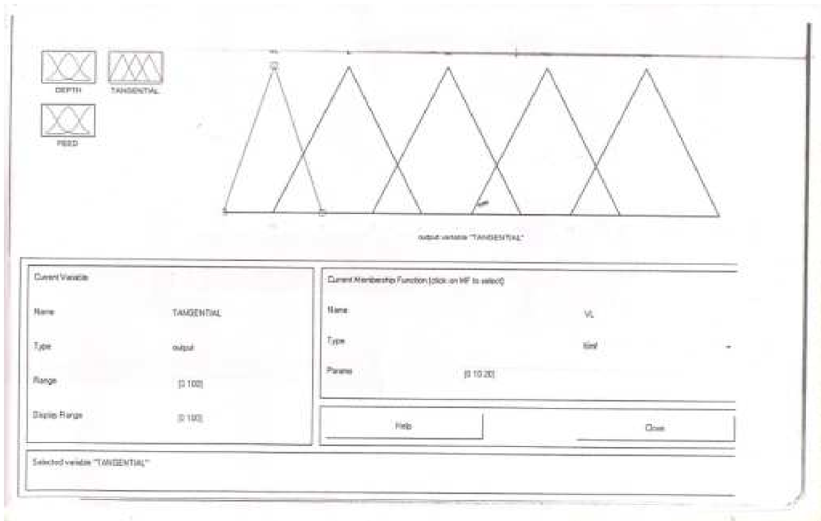
micro controller and result of feed rate, depth of cut and Tangential force are analyzed with MAT-Lab.



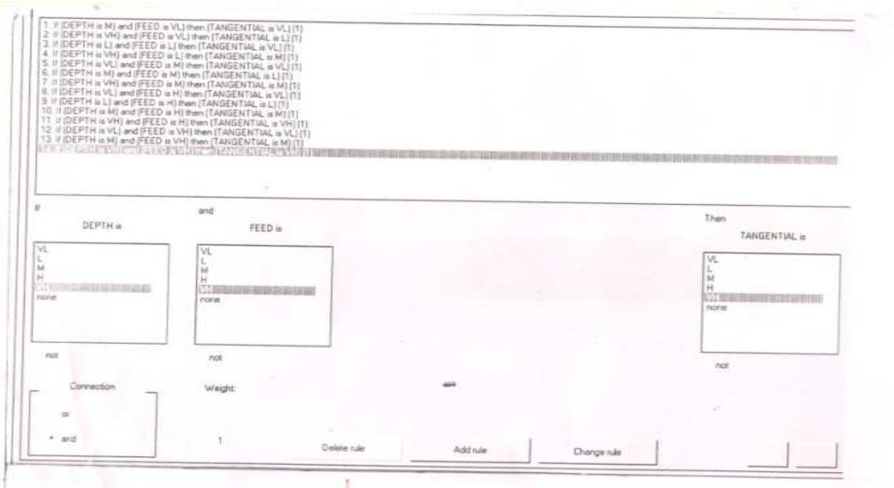
Graph 1:Input Variables for Depth of Cut



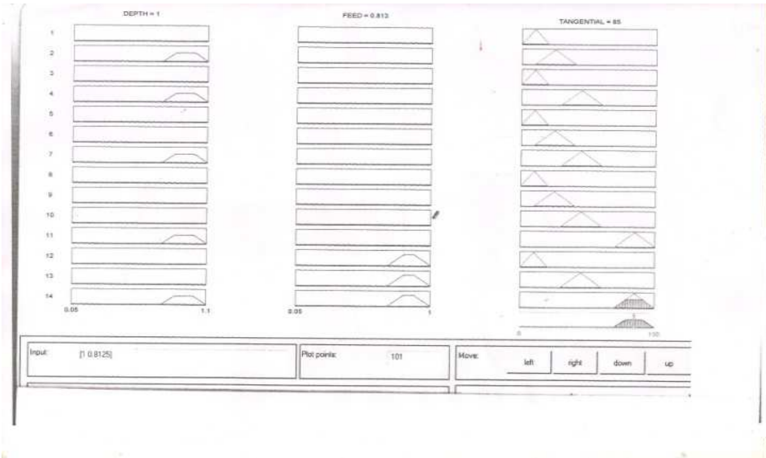
Graph 2: Input Variable for Feed Rate



Graph 3: Input Variable for Tangential Force



Graph 4: Input of Fuzzy Variables



Graph 5: Feed Rate, Depth of Cut and Tangential Force

REFERENCES

1. *Fuzzynet technical case studies*, http://www.aptronix.com/
2. Weijing Zhang, *Applications Engineer*, Aptronics Incorporated, Copyright © 1992 by Aptronix Inc.
3. Shabiul Islam, Shakowat, *"Development of a Fuzzy Logic Controller Algorithm for Air Conditioning system"*, ICSE 2006Proc-2006 IEEE.
4. M. Spott and D. Nauck, "*Towards the Automation of Intelligent Data Analysis"*, Appl. Soft Comput. 6(2006), 348 -356.
5. Zain, Z. M.; Kauntan; Abdullah,N. H; Hanafi, A. H. M – "*Microcontroller Based Energy Saving Control for Air-Conditioning System Using Fuzzy Logic Approching*; An overview, Research and Development, 2006, SCOReD 2006, 4th student Conference on date 28-28 June 2006.
6. K. S. Rattan and G. S. Sandhu, *"Analysis and Design of Proportional Plus Derivative Fuzzy logic controller*, Proc.National Aeronautics and Electronics Conference, Dayton,1996.
7. L. A. Zadah, "*Fuzzy sets"*, Inform. and contr., vol.8, pp. 338-353, 1965.

8. M. Sugeno,Ed: "*Industrial Application of Fuzzy Control"*, North-Holland(1985).
9. Zhang. J and LANG. S., "*Explicit Self Turning Control for a Class of nonlinear System*", Automatica, 1989.25,(4), pp. 593 -596.